

**Final Technical Report  
for Grant NAG 5-2963**

**Solar cycle dynamics of  
solar, magnetospheric, and heliospheric particles,  
and long-term atmospheric coupling:  
SAMPEX**

**Period: July 1, 1995 - September 30, 2000**



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## *Final Technical Report*

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### **Solar cycle dynamics of solar, magnetospheric, and heliospheric particles, and long-term atmospheric coupling: SAMPEX**

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### **Summary**

This final technical report summarizes science analysis activities by the SAMPEX mission science team during the period July 1, 1995 through September 30, 2000. Bibliographic entries for 1995 to date (October 2000) are included. The SAMPEX science team was extremely active, with 72 articles published or submitted to refereed journals, 38 papers published in their entirety in Conference Proceedings, and 260 contributed papers, seminars, and miscellaneous presentations. The bibliography at the end of this report constitutes the primary description of the research activity. Science highlights are given under the major activity headings, as well as other activities of the team.

One Ph.D. student, Mr. Daniel Williams, completed his thesis at California Institute of Technology based on data from the MAST instrument.

## Scientific Investigations

### a) Solar and Interplanetary Energetic Particles

Solar energetic particle (SEP) charge states were studied using the LICA, and MAST sensors, with reports generated independently for each of them. These studies concentrated on the October/November 1992 solar particle events and the November 1997 large SEP event, which were the only ones so far during the mission that generated fluxes high enough to be used for comprehensive charge state measurement by LICA and MAST.

Corotating Interaction Regions (CIRs) have been the most frequent sources of energetic particles during the 1995-97 time period, and have been studied with the high sensitivity LICA sensor, with an emphasis on composition and correlation with the Ulysses mission.

Examples of results reported on these subjects during the grant period were:

- A comprehensive study of the isotopic composition of SEP heavy ions measured with MAST was published, and also formed the basis of a Ph.D. thesis by Daniel Williams of the California Institute of Technology. Dr. Williams graduated in late 1998. This work found Ne isotopic composition more similar to solar system abundances than earlier measurements.
- Charge states of low energy SEP ions were measured with the LICA experiment for the November 1997 event, and published in a special issue of Geophysical Research Letters containing a special section of ACE results and related science topics. Low ionization states for SEP ions, first reported from LICA from the November 1992 event, were seen again, although with an energy dependence in ionization state in the region below 1 MeV/nucleon. This general trend was confirmed by the SEPICA instrument on ACE, although some discrepancies remain to be understood.

- A comprehensive study of the CIR properties during the Ulysses mission epoch was completed, using LICA, Ulysses, and IMP data. The global structure and connectivity between Earth and the Ulysses location was elucidated, and the general radial and longitude dependence of the CIR intensities revealed.

## b) Magnetospheric Studies & Space Weather

Numerous studies were carried out of magnetospheric particles and space weather effects. Some of these were collaborative works using the ISTP spacecraft, as well as ground based measurements from the EISCAT radar:

- A study was carried out of the May 12, 1997 solar event, which had a strong effect on the middle atmosphere. Electron fluxes measured on SAMPEX, along compared with the increase in NO<sub>x</sub> compounds in the upper atmosphere following the event, gave a striking example of the coupling between energetic particles and atmospheric chemistry.
- A statistical study of the polar cap boundary was carried out using SAMPEX high sensitivity instruments, using "expert system" software to identify the cap boundaries. This study was much more comprehensive than earlier ones, and revealed a weak, but significant dependence of the boundary location on magnetospheric activity indices such as K<sub>p</sub>.
- A 6 1/2 year survey of Equatorial Ions was completed, using the LICA instrument. These low energy ions are believed to originate in the ring current, where they can charge-exchange with neutrals, then moving on a ballistic trajectory since they have no net charge. If they subsequently encounter the upper atmosphere, they can lose an electron and become trapped again, but only for a short duration. Discovered in the 1970s, there have only been a few reports of these ions. The comprehensive SAMPEX survey showed them to be a feature of most (but not all) years of the solar minimum period, and correlated with the incidence of magnetic storms.

- SAMPEX global maps of the magnetosphere were used to continue our studies of the global energization and transport of energetic particles.
- Electron precipitation in the dayside low-latitude boundary layer was studied, in order to probe the magnetic topology of the layer. It was found that the equatorward edge of the energetic electron precipitation coincides precisely with the equatorward edge of the LLBL (Lower Latitude Boundary Layer) as these boundaries move over a wide range of invariant latitude.

### c) Anomalous Cosmic Rays

Analysis of the anomalous component of cosmic rays (ACRs) continued; examples of results presented during the grant period was:

- discovery of multiply charged anomalous cosmic rays. This completely unexpected finding puts important constraints on the location and mechanisms of ACR acceleration.
- a survey of minor ions in the ACRs, including Carbon. These ions, also observed by instruments on the Wind spacecraft, involve species that are mostly ionized in the local interstellar space, and are therefore not candidates for become ACRs by the mechanism that energizes ACR N, O, and Ne. Their presence may point to the existence of other sources of neutral and singly charged ions in the inner heliosphere.

## Data Analysis Activities

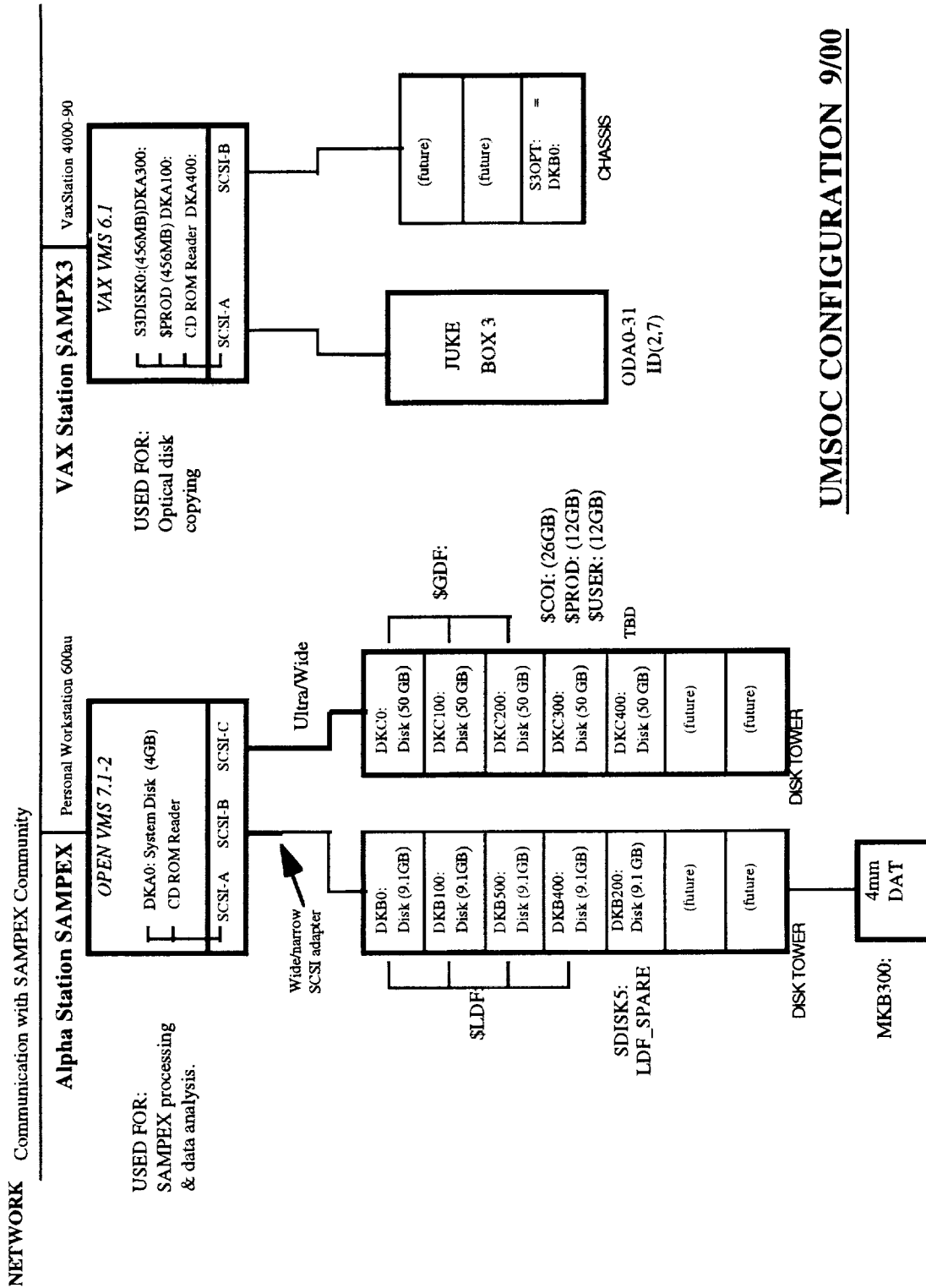
Data analysis at the University of Maryland Science Operations Center (UMSOC) was routine, with Level-1 MDFs sent out to the investigator team approximately 2-3 weeks after receipt.

During the grant period, we supported the transition to the PACOR-II facility, wherein data was sent to UMSOC by the internet using the Goddard Data Distribution Facility (DDF) and a dedicated Sparc-station at UMSOC. Later, a further change was supported, wherein the transmission to UMSOC was done by the Goddard "Data Processing System" using standard FTP "puts". This removed the need for the Sparc-station and associated software. The transition to the DPS was completed in June, 1999.

In order to better handle the SAMPEX data set, which is much larger than originally anticipated due to the length of the mission, a new workstation was purchased for UMSOC during this grant period: a DEC personal digital workstation 600au (alpha station). This workstation is much faster than any of the VAXstations in the existing cluster, and it can process a 24-hour long data set in ~10 minutes compared with >2.5 hours for the older workstations. This extra speed is of great help in routine data processing, and also for science processing. Additional disk space was added to UMSOC to handle the growing data set, and to provide on-line access to all members of the science team. The accompanying figure shows the configuration of UMSOC as of September 2000.

In the transition of software to the new alpha station, Y2K issues were systematically addressed. The transition to Y2K was smooth and without incident.





**UMSOC CONFIGURATION 9/00**

## NSSDC Submission

Large team efforts continued in support of calibrated flux files for 30s averages, and polar cap average data for NSSDC. The data submission to NSSDC is in the form of "flatfiles", which contain 24 hours of 30s data, and also 1 month of polar cap average data. Submission to NSSDC is being carried out by rewritable optical disk which is done simultaneously with the submission of our basic "MDF" data sets to NSSDC.

NSSDC personnel have generated the requisite tables to convert the flatfiles into CDF.

The current (10/3/00) data submitted to the NSSDC is:

### **SAMPEX data submitted to the NSSDC**

Data Type	Period Covered:
30 second rates	July 6, 1992 - August 31, 2000
30 second fluxes	July 6, 1992 - August 31, 2000
Polar cap averaged rates	July 1992 - August 2000
Polar cap averaged fluxes	July 1992 - August 2000

## Solar Geophysical Data Bulletin Submissions

SAMPEX Interplanetary Particle Fluxes for the period Jan-Jun 1995 appeared in the April 1996 (#620) issue of Solar-Geophysical Data (SGD) Comprehensive Reports. A summary of the submissions to date is below. Submission of these plots has fallen behind our earlier schedule due to the loss of a key person at Caltech. In the September 2000 science working team meeting, the Caltech group presented a new plan to catch up with these plots, and to keep them up to date. These plots will also be posted on-line on the SAMPEX web page.

Dates of data	SGD vol.	SGD issue date
Jul-Dec 1992	#595	March 1994
Jan-Jun 1993	#596	April 1994 - revised in issue #606
Jan-Dec 1993	#606	February 1995
Jan-Dec 1994	#618	February 1996
Jan-Jun 1995	#620	April 1996
Jul-Dec 1995	#632	April 1997
Jan-Feb 1997	#633	May 1997
Mar-Dec 1997	#647	July 1998

## World Wide Web site

The SAMPEX WWW site (<http://surya.umd.edu/www/sampex.html>) has had over 13,000 accesses by non-team members for the period Jan 5, 2000 to Sept. 7, 2000, or roughly 1400 hits per month. About 2000 of these were from Europe, Asia, and Canada. The page layout contains sub-sections:

### INTRODUCTION:

- An overview of the page

### SPACECRAFT

- Description of the spacecraft, its subsystems and orbit.

### INSTRUMENTS

- Instrument descriptions, their science objectives and full publications.

### SCIENCE

- Examples of scientific investigations together with data and images and list of SAMPEX discoveries.

### RECENT RESULTS

- A compendium of brief science results and supporting figures used in reports to NASA Headquarters

### PEOPLE

- People and institutions comprising the SAMPEX collaboration.

### OUTREACH

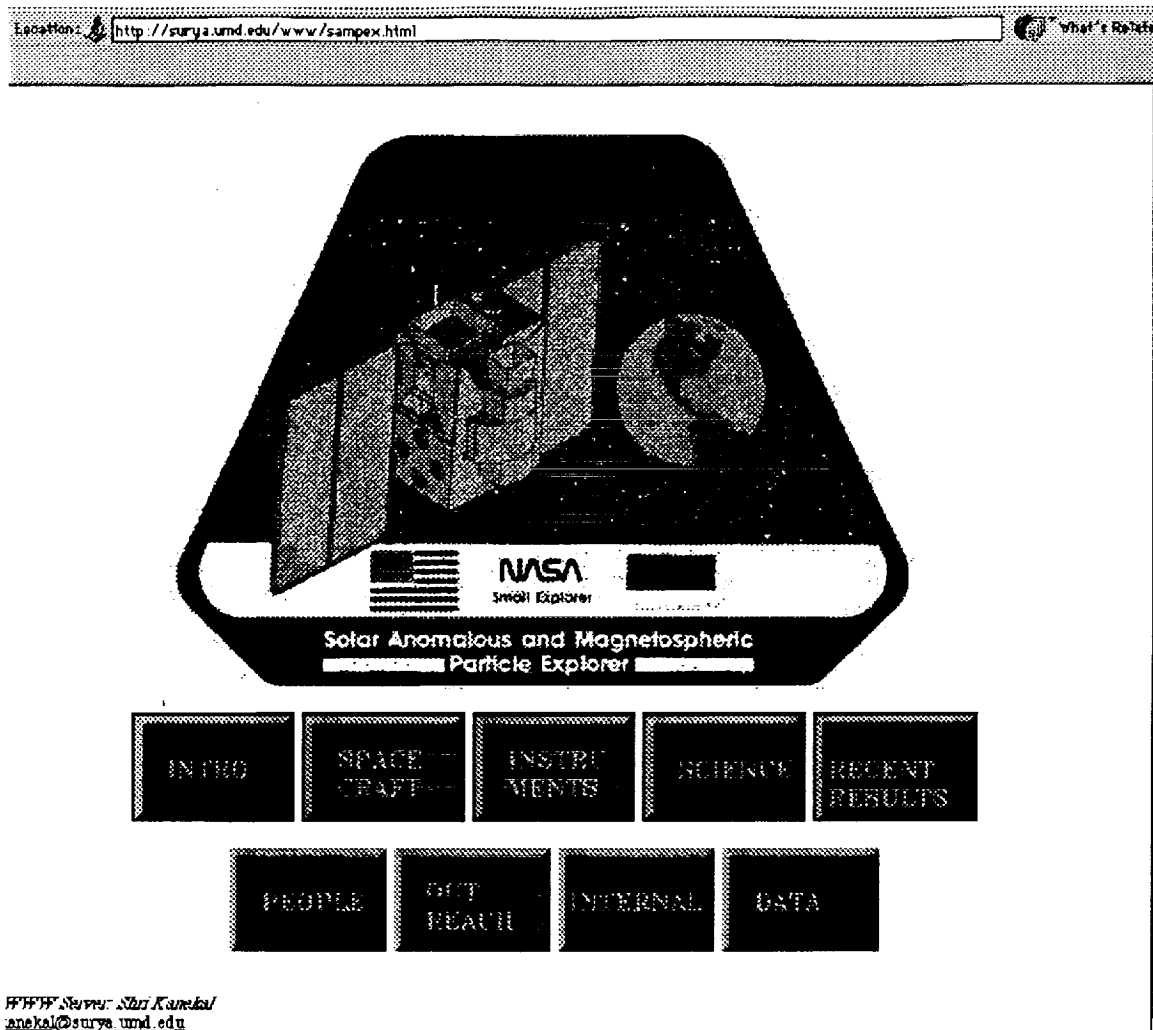
- Descriptions of the SAMPEX operations at Bowie State Operations Center, and at the Cooperative Satellite Learning Project in Laurel, MD.

### DATA

- Science data in the form of plots and images, including all monthly plots that appear in the *Solar Geophysical Data* books

### SAMPEX INTERNAL MEMOS

*SAMPEX web page welcome page*



## Team Meetings

Team meetings are held to exchange results, coordinate current and future analysis projects, and plan future spacecraft/instrument operations. Meetings held during the reporting period are listed below.

### *SAMPEX science team meetings 1995 - 2000*

SWT Meeting Number	Location	Date
13	Caltech, Pasadena, CA	Feb 5-6, 1996
14	U of Colorado, Boulder, CO	Jan 28-29, 1997
15	Pertisau, Austria	Sept 29 - Oct 1, 1997
16	Hampton, VA	May 4-5, 1998
17	Caltech, Pasadena, CA	Feb. 18-19, 1999
18	Estes Park, CO	Sept 16-18, 1999
19	Kihei, Maui, HI	Jan 10-12, 2000
20	Pertisau, Austria	Sept 18-20, 2000

## Spacecraft & Instrument Health and Operations

The SAMPEX spacecraft and instruments remained in excellent operating condition. Highlights during the period were:

The spacecraft remains in 1 rev per orbit mode, which was entered on May 7, 1998. This mode is optimal for solar particle event ionization state studies. The team will continue reexamine the operations in this mode from time to time in order to determine the observing strategy expected to yield maximum science returns.

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